

Working paper



International  
Growth Centre

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March 2012

When citing this paper, please  
use the title and the following  
reference number:  
F-40003-TZA-1

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March 28, 2012

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*This paper is the outcome of research collaboration between staff of the Department of Economic Research and Policy at the Bank of Tanzania and the International Growth Centre. The views expressed in this paper are solely those of the authors and do not necessarily reflect the official views of the Bank of Tanzania or its management. All errors are those of the authors.*

In the vast majority of low-income countries, financing and political constraints have traditionally impaired the usefulness of fiscal policy as a short-run stabilization device. Indeed, it is widely recognized that fiscal policy in such countries has very often tended to be pro-cyclical. While fiscal dominance has also impaired the effectiveness of monetary policy, this situation has been changing, as many low-income countries have increased the independence of their central banks. These newly-independent central banks have taken center stage in the conduct of short-run macroeconomic stabilization in such countries, not just because they are in a position to exploit the traditional flexibility advantage of monetary policy, but also because they tend to be the primary locus of macroeconomic expertise in low-income countries.

The ability of central banks to carry out this stabilization function, however, depends on the strength and reliability of the links between the policy instruments that they control and aggregate demand – i.e., on the effectiveness of monetary transmission. Unfortunately, this effectiveness cannot be taken for granted. There are at least three reasons for concern. First, in the industrial-country context in which this issue has been most thoroughly investigated, the effectiveness of monetary transmission has long been a controversial question, and a professional consensus on the ability of monetary policy to affect real output has only recently been achieved. Even so, the strength of this effect, the channels through which it operates, and the extent of output variability for which it can account all remain unsettled issues. Second, it is widely acknowledged that the channels through which monetary policy affects aggregate demand depend on a country's financial architecture: the size and composition of its formal financial sector, the degree of development of its money, bond, and stock markets, the liquidity of its markets for real assets such as housing, the extent of its links with external financial markets, and its exchange rate regime. Given that these characteristics of the financial environment differ markedly between low-income countries and industrial countries, there is little reason to expect that results about monetary transmission derived for industrial countries would necessarily extend to low-income countries.<sup>1</sup> Third, the evidence that exists for low-income countries is not very reassuring. Careful studies of the effectiveness of monetary transmission in such countries have often found effects that are counterintuitive, weak, and/or unreliable.<sup>2</sup>

The time is therefore right to undertake a systematic exploration of this issue. This paper proposes a template for doing so, using the example of Tanzania as a case study. Its objective is to develop a systematic approach to the investigation of the effectiveness of monetary transmission in low-income countries that can be applied specifically to the five EAC countries. Our procedure is as follows:

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<sup>1</sup> See Mishra, Montiel, and Spilimbergo (2011b).

<sup>2</sup> Mishra, Montiel, and Spilimbergo (2011a).

1. We identify the key components of the financial architecture that *ex ante* are likely to play a role in the effectiveness of monetary transmission and describe how these components have evolved in the country over time. The relevant components, as indicated above, are:

- The extent of the country's effective links with external financial markets.
- The country's exchange rate regime.
- The country's financial structure – i.e., the size and composition of its formal financial sector, and the degree of development of its money, bond, and stock markets, as well as of its markets for real assets.

There are three reasons to begin with such descriptive material. First, it provides an *ex ante* expectation regarding the effectiveness of monetary transmission. For example, the well-known open-economy “trilemma” suggests that a country with a high degree of integration with international capital markets, and a “hard” exchange rate peg (an industrial-country example would be Hong Kong) would be expected to exhibit very weak monetary transmission to domestic aggregate demand, as monetary policy actions would primarily be expected to influence capital flows. A formal investigation that suggested the opposite would present a puzzle to be resolved. Second, the description of the country's financial “architecture” may help identify relevant variables that should be included in the formal analysis. For example, if stock markets are small and highly illiquid, there would be little point in including a stock price index in a formal study of monetary transmission. Third, the descriptive background helps to identify potential discontinuities in the financial architecture that would create instability in the transmission mechanism, and thus suggests specific sample periods over which we can expect to observe a stable mechanism.

2. We attempt to identify how monetary policy was conducted during the relevant sample period. In other words, we seek answers to question such as:

- What objectives was monetary policy seeking to achieve? Typically this involves some combination of a price level objective, real economic activity, and/or an exchange rate/foreign exchange reserve objective, possibly constrained by a financial stability objective.
- What instrument did the monetary authorities employ in seeking to achieve this objective? This may be an interest rate, the exchange rate, or some financial aggregate such as narrow or broad money, or the stock of central bank credit.
- What (broadly defined) rule did the authorities follow in adjusting their instrument to attain their objective(s)? This essentially concerns the links between the policy instrument and the observables that are monitored by the authorities in choosing the desired values of that instrument.

3. We provide a descriptive basis for identifying potentially important exogenous influences on aggregate demand in the country. Typically, these will consist of external real and possibly financial variables, such as partner-country price levels, the price of an important import such as food or fuel, or the country's terms of trade.
4. We attempt to establish the time series properties of the endogenous variables to be included in our investigation: specifically, their degree of stationarity and the presence or absence of cointegrating relationships among them.
5. Based on the results of (4), we estimate a reduced-form VAR in levels, error-correction, or first-differenced form. We ensure that the estimated VAR is well-behaved, in the sense that its lag length is appropriate and its residuals are white noise.
6. Again based on descriptive country material, we formulate an identification scheme for extracting the structural residuals from the reduced-form VAR residuals.
7. We evaluate the power and reliability of monetary transmission by examining the magnitude of the response of the aggregate demand variable(s) over time to a monetary policy impulse – i.e., the magnitude and precision of the impulse response functions (IRFs) linking monetary policy innovations to indicators of aggregate demand such as the price level and the level of real output.
8. Assuming that effects of monetary policy on aggregate demand indicators are identified, we examine the roles of specific transmission channels by supplementing our baseline VAR with variables that serve as indicators of specific potential transmission channels and examining both the effects of the monetary policy impulse on such variables, as well as the implications for the effects of the monetary impulse on the aggregate demand variable(s) of treating the transmission variable as exogenous in the calculation of the impulse responses.<sup>3</sup>

In the remainder of this paper we implement this procedure for Tanzania, following the order outlined above. The first two sections of the paper are devoted to steps 1 and 2. The third section discusses the empirical methodology in more detail. The heart of the paper is in sections 4 and 5, which implement steps 4-8 in a relatively simple setting with three endogenous variables and a more complicated one with six variables. A concluding section evaluates the usefulness of the exercise in drawing conclusions about the effectiveness of monetary transmission in Tanzania.

## **I. Capital Account Regime, Exchange Rate Regime, and Domestic Financial Structure**

In this section we describe the aspects of Tanzania's financial architecture that are relevant in determining the strength of monetary transmission: the country's links with international capital markets, its exchange rate regime, and its domestic financial structure. As it

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<sup>3</sup> This technique was introduced into the analysis of monetary transmission by Ramey (1993).

happens, the Tanzanian financial system has undergone enormous changes over the past two decades. We describe these changes, both to identify the most recent period during which we may expect to observe a stable monetary transmission mechanism, as well as to formulate an *ex ante* expectation of how that mechanism might function based on the financial structure to which Tanzania has (tentatively) converged.

### *1. Financial integration*

During the post-2000 period, Tanzania maintained an extensive system of *de jure* restrictions on capital movements (based on the IMF's *Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER)* as well as on the Chinn-Ito 2009 indicator), which was consistent with relatively limited *de facto* capital mobility. The IMF's *AREAER* reports that Tanzania still maintains a wide range of restrictions on capital-account transactions. The Chinn-Ito measure consists of an index in which larger values correspond to fewer restrictions on international financial transactions. For the sake of comparison, by their measure the index value for the United States was 2.54 during the entire 1970-2009 period, while that for Japan increased from -0.09 in 1970 to 2.54 in 1983, following a process of financial liberalization in that country. The index for Tanzania, by contrast, registered -1.13 continuously from 1996 to 2009. The *de jure* indicators thus suggest a very limited amount of capital mobility in Tanzania during recent years.

The Dhungana *de facto* integration measure is based on the Milesi-Ferretti and Lane (2006) approach to measuring effective financial integration, which in turn is based on the ratio of the sum of a country's total gross external financial assets and liabilities to GDP. Dhungana adjusts this measure by excluding concessional financing and holdings of foreign exchange reserves. His measure is available most recently for the year 2007. Again using the United States and Japan as benchmarks, this ratio was 2.78 for the United States, and 1.72 for Japan. For Tanzania, it was 0.53.

*Overall, then, objective de jure and well as de facto indicators concur in suggesting that Tanzania has enjoyed only a limited degree of de facto integration with international financial markets during recent years. This suggests that the BoT should be expected to retain monetary autonomy even during periods in which it engages in extensive intervention in the foreign exchange market to stabilize the exchange rate.*

### *2. Exchange rate regime*

The correct identification of the exchange rate policies actually pursued by countries, as opposed to their declared policies, has recently been recognized as a major challenge, as it has become apparent that countries do not always do what they say they do in the area of exchange rate management. In addition to reporting on the presence of capital account restrictions, the IMF's *Annual Report on Exchange Arrangements and Exchange Restrictions* now provides a *de facto* measure of each country's official exchange rate regime – i.e., a measure based on what

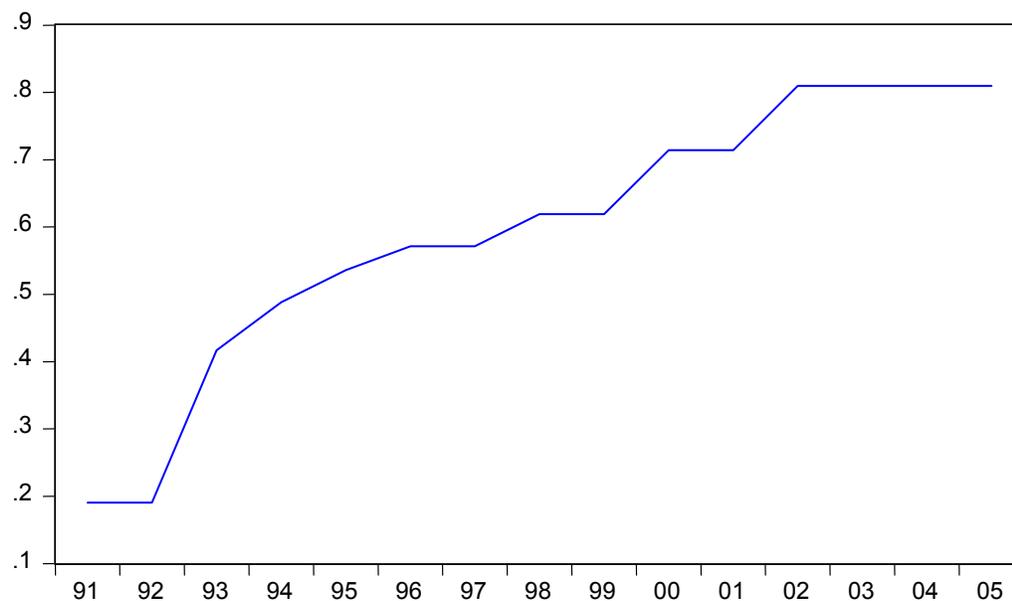
countries do, rather than on self-declarations. Tanzania’s regime has been classified in the *AREAER* as a “managed float with no predetermined path for the exchange rate” during recent years. According to Reinhart and Rogoff as well, Tanzania maintained an exchange rate regime best characterized as a managed float.

*The retention of some (unspecified) degree of exchange rate flexibility has two implications for monetary transmission in Tanzania: it provides an additional reason why the BoT should be expected to retain a meaningful degree of monetary autonomy, and it allows for the possibility that central bank actions can be transmitted to the economy through an exchange rate channel, since the exchange rate is, at least in principle, an endogenous variable in Tanzania.*

### 3. Financial reform

A process of liberalization and reform of the Tanzanian financial system was launched in 1991 as the result of the publication of the Nyarabu Commission report on the state of the system. To get a sense of what has transpired, Figure 1 displays a composite index of *de jure* domestic financial reform compiled by IMF staff.<sup>4</sup> This index is normalized to range from zero to 1 (with 1 indicating a fully liberalized system). It demonstrates that the decade of the 1990s was one of extensive reform of the financial sector in Tanzania, but nonetheless that the process stopped short of complete liberalization in the early 2000s.

Figure 1. Tanzania: IMF Financial Reform Index, 1991-2005



<sup>4</sup> The index was taken from Giuliano et al (2010).

Financial development followed financial reform with a lag, however. While interest rates were liberalized in 1991 and the entry of private banks was permitted in 1992, none began operations until 1994, and the banking system began to expand dramatically only after 1998. In 1998, Tanzania had 18 commercial banks with 178 branches, but by 2009 the number of commercial banks had increased to 31 with 407 branches. Bank deposits amounted to less than 3 percent of GDP in 1998, yet by 2000 they had increased to over 12 percent of GDP, and they continued to increase over the subsequent decade, amounting to some 25 percent of GDP by 2009. Similarly, bank credit to the private sector expanded from under 4 percent of GDP in 1998 to 15 percent by 2010, and non-performing loans (NPLs), which were about 23 percent of GDP in 1998, had been reduced to slightly over 6 percent by 2008. As of end-2009, in addition to the 31 commercial banks, Tanzania had 9 non-bank financial intermediaries, a stock exchange, and several other types of financial institutions. Banks account for about 80 percent of financial system assets, and foreign equity accounts for about 2/3 of bank capitalization.<sup>5</sup> It is clear that the process of monetary transmission in Tanzania must have been dramatically altered by these changes, and the transmission mechanism that has evolved over the past decade can therefore be expected to be fundamentally different from what it was previously.

*This suggests that investigation of the monetary transmission mechanism in Tanzania should be based on post-2000 data.*

#### *4. Domestic financial structure*

##### a. Role of the formal financial sector

Tanzania's financial sector continues to be dominated by banks, with the banking system holding more than three-quarters of total financial sector assets in 2009. However, despite the rapid growth of the Tanzanian banking sector, it remains relatively underdeveloped – not just relative to advanced and emerging economies (Table 1), but even compared to other low-income countries and to other countries in the region. The regional average of private credit to GDP, for example, was 28 percent in 2009, and the ratio of bank deposits to GDP was 44 percent (compared to 16 and 25 percent for Tanzania respectively). In addition to its small size, there are reasons to question the effectiveness of Tanzania's banking sector in transmitting monetary impulses to aggregate demand. Only 16 percent of Tanzanians have access to the formal financial sector, which is the lowest ratio in the region (IMF 2010).

##### b. Cost of lending

Indeed, loans and advances represented only about a third of banking sector assets in Tanzania on average during the 2000's (though that share was growing over time), and much of this lending has been channeled to a few large firms, which may also be able to tap external

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<sup>5</sup> These figures are from Nord et al (2009).

**Table 1. Tanzania: Indicators of Financial Development**

	<b>Advanced</b>	<b>Emerging</b>	<b>Low- Income</b>	<b>Tanzania</b>
<b>Size of banks and other financial intermediaries</b>				
Deposit bank assets/GDP	1.24	0.63	0.32	0.18
Other financial institutions assets/GDP	0.55	0.17	0.06	--
<b>Bond market development</b>				
Private bond market capitalization/GDP	0.51	0.12	0.00	--
Public bond market capitalization/GDP	0.46	0.29	0.43	--
<b>Bank concentration</b>				
Net interest margin	0.02	0.05	0.06	0.06
Bank concentration	0.67	0.57	0.73	0.49
<b>Stock market development</b>				
Stock market capitalization/GDP	0.90	0.82	0.27	0.04
Stock market total value traded/GDP	0.79	0.53	0.02	0.02
Stock Market turnover ratio	0.77	0.61	0.11	0.00

markets.<sup>6</sup> The implication is that smaller firms and households in Tanzania may be little affected by changes in the supply of bank lending.

c. Organization of the banking industry

A separate issue is the extent to which the supply of bank lending may be affected by the monetary policy actions of the central bank. There is an extensive literature exploring the effects of the structure of the banking industry on banks' responses to monetary policy actions. Cottarelli and Kourelis (1994), for example, argue that in less competitive banking systems (those that face less competition from nonbank intermediaries and in which the banking sector is itself more concentrated), and in situations in which the interbank market is thin, monetary policy actions are less likely to be transmitted to bank lending rates. In the first case, the reason is that the cost to banks from failing to adjust the lending rate in response to a change in the cost of funds is increasing in the elasticity of demand for loans. Since less competitive banking means less elastic loan demand facing individual banks, if there are costs to adjusting loan rates banks will find it less profitable to incur those costs in response to monetary policy changes the less competitive the banking system. In the second case, with a thin interbank market, interbank rates will prove to be volatile, and banks will therefore face a more challenging signal extraction problem in distinguishing "permanent" changes in the interbank rate caused by monetary policy from "transitory" ones caused by random events in the interbank market. In the face of fixed costs to adjusting loan rates, this will also make bank loan rates less sensitive to monetary policy.

As shown above, Tanzania's banking sector faces limited competition from nonbank financial intermediaries. Moreover, the country's banking industry is highly concentrated, with the 3 largest domestic banks and four largest international banks holding nearly 80 percent of total bank assets. Indeed, the view that the degree of competition in Tanzania's banking sector may be limited is supported by evidence of collusive behavior on the part of large banks in the BoT's Treasury bill auctions (see Abbas and Sobolev 2008). At the same time, the interbank market is extremely limited in Tanzania, and the T-bill market has become highly volatile in recent years.

*Thus, both of the factors emphasized by Cottarelli and Kourelis would suggest that transmission from BoT policy actions to bank lending rates may be impaired in Tanzania.<sup>7</sup> This*

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<sup>6</sup> Nord et al (2009) have estimated that lending to large corporations accounts for up to 70 percent of Tanzanian banks' loan portfolios.

<sup>7</sup> It is worth noting that some bank characteristics that have been associated with weaker monetary transmission in the industrial-country literature should not be expected to operate in the same way in the Tanzanian context. In particular, it has been argued that larger banks, and banks that hold a larger proportion of their assets in government securities, are less likely to have their supply of loans affected by monetary policy (Kashyap and Stein 2000). The reasoning is that, to the extent that monetary policy affects the supply of resources to these banks through its effect on bank deposits, larger banks are in a position to offset those effects by altering their security issuance, and more liquid banks are more able to do so by altering the share of securities in their asset portfolios. But both of these responses rely on the presence of a liquid secondary securities market, which is rarely the case in low-income countries such as Tanzania.

*suggests that empirical results regarding the ultimate effects of central bank policies on aggregate demand in Tanzania may usefully be interpreted by investigating transmission through commercial bank lending rates.*

## 5. Summary

This overview indicates that conflicting forces are at work in determining the strength of monetary transmission in Tanzania. We can usefully separate these forces into two categories: macroeconomic factors and microeconomic ones.

- On the one hand, the combination of limited capital mobility and a fairly flexible exchange rate regime suggests that the BoT should retain substantial monetary autonomy. Limited capital mobility means that in the face, say, of a tightening of monetary policy, domestic banks would not find it easy to sustain lending by accessing foreign funds, while bank customers would not find it easy to offset reduced domestic bank lending with increased foreign borrowing. Flexible exchange rates mean at the same time that, to the extent that tighter monetary policy would indeed induce capital inflows either to domestic banks or to their customers, the BoT would not find itself compelled to reverse its tightening by an obligation to purchase the increased supply of foreign exchange. Moreover to the extent that it chooses to absorb some of the increased supply of foreign exchange to stabilize the value of the currency, it would not have to issue base money in order to do so, since imperfect capital mobility allows it to sterilize its foreign exchange market intervention. In short, the *macroeconomic* factors are consistent with the retention of monetary autonomy on the part of the BoT and therefore with the effectiveness of monetary transmission to aggregate demand.
- On the other hand, the *microeconomic* factors point in the opposite direction: the uncompetitive structure of Tanzania's banking sector and the absence of a liquid interbank market both suggest that BoT monetary policy actions may have weak effects on bank lending rates, while the small size of the formal financial sector and the dominance among banks' loan customers of large corporations with likely access to external funds together suggest that changes in commercial bank lending rates may have weak effects on aggregate demand, and therefore on prices and/or output.

In short, there are macroeconomic reasons to believe that the Bank of Tanzania has retained its monetary autonomy over the past decade, but this leaves open the question of whether, in exercising that autonomy, the BoT has been able to effectively influence aggregate demand. There are microeconomic reasons to suspect that its influence may have been limited.

## II. Monetary Policy Regime

The effectiveness of monetary policy in Tanzania is examined empirically by estimating the extent to which an exogenous change in monetary policy induces changes in macroeconomic variables – such as prices or output – that respond to changes in aggregate demand. Providing formal statistical evidence on the effectiveness of monetary transmission therefore confronts several serious methodological challenges. First, the exercise requires an empirically observable indicator of the stance of monetary policy. Second, having identified the indicator of policy, it is necessary to discriminate between policy *innovations* (unanticipated changes in policy) and policy *actions* (including both anticipated and unanticipated policy changes). The reason is that the economy's reaction to anticipated policy changes consists of the combined effects of the policy itself as well as those of the shock that triggered the policy change. Our interest is in the former, not the latter. Third, to identify an exogenous policy change, the innovation in monetary policy must be decomposed into the portion that reflects merely a *contemporaneous* response of monetary policy to other macro shocks and the portion that represents a true exogenous innovation in monetary policy, since it is only the effects of exogenous monetary policy shocks that we are interested in.

In effect, this means that in order to proceed, we will need to identify the BoT's monetary policy reaction function. In the case of Tanzania, there appears to be wide agreement on the broad outlines of this function. Specifically, in the year 2000 the BoT adopted reserve money targeting as its immediate operating target and broad money as an intermediate target, with the ultimate objective of monetary policy being the achievement of price stability.<sup>8</sup>

*This suggests a monetary policy reaction function with reserve money as the dependent variable and observable variables expected to be correlated with future inflation as independent variables. In light of the high-frequency public observability of the floating exchange rate and of the use of broad money as an intermediate target (a variable which should be continuously observable by the central bank), we would expect the desired setting of reserve money to depend on the contemporaneously-observed values of these two variables, as well as possibly on external variables (such as international food and fuel prices) that may be perceived by the BoT as affecting future headline inflation in Tanzania.*

Given the price stability objective, we should expect that positive innovations in variables that are expected to be positively correlated with future inflation should be associated with contractions in reserve money, and verifying that the estimated reaction function indeed exhibits these properties would increase our confidence that we have indeed identified true exogenous monetary policy shocks.

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<sup>8</sup> The inflation rate, which had hovered in the 20-30 percent range since 1985 but had hit levels in excess of 80 percent during 1994, had indeed been brought down to single-digit levels by the beginning of the 2000s, consistent with a worldwide trend of reduced inflation during this period.

### III. Formal Methodology

These challenges mentioned in the last section can be addressed in two alternative ways: using structural models or VARs. Ever since Sims (1980) made the case that the exclusion restrictions required for empirical structural macroeconomic models were unconvincing, VAR estimation has become the methodology of choice for the investigation of the effects of monetary policy in industrial countries, and there is now a substantial literature applying VAR methods to investigate monetary transmission in emerging and low-income countries as well.<sup>9</sup> The VAR approach has particular advantages over model-based approaches in the low-income country context, where the poorly-understood functioning of the economy at the macroeconomic level makes the exclusion restrictions required in structural approaches even less credible than they are in the advanced-country context. We shall therefore apply that approach in what follows.<sup>10</sup>

Applying the VAR methodology in this context involves the following steps:

1. Choose a parsimonious specification for the VAR. A low dimensionality is important, because capturing the true dynamic interactions among the monetary policy instrument, the information variables that enter the central bank's reaction function, and the variables targeted by policy may require a long lag structure, rapidly using up degrees of freedom. In the case at hand, a three-variable specification would appear to be the minimal one, since we need to account for the monetary policy variable, at least one information variable in the central bank's reaction function, and an indicator of aggregate demand. It is important to emphasize that what is essential here in order to avoid specification error is to correctly identify the exogenous monetary policy shock. We do not have to account separately for the potential influence of non-monetary variables on the behavior of the target variable that interests us, because if we succeed in capturing the exogenous monetary policy innovation, that innovation will be uncorrelated with any nonmonetary variables that may affect our target variable, and thus the estimated dynamic response of the target variable to the monetary shock will not be subject to omitted-variable bias.
2. Identify the time-series properties of the VAR variables, to determine whether estimation in levels, in first-differences, or in error-correction form is appropriate.
3. Having determined the appropriate form of estimation, choose a lag length that is sufficient to remove all serial correlation from the VAR residuals.
4. Examine the contemporaneous correlation among the resulting VAR residuals. If these correlations are nonzero (as they generally are) specify an analytical model that explains these correlations as the outcome of economic relationships among underlying mutually uncorrelated

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<sup>9</sup> For a survey of VAR studies of monetary transmission in low-income countries, see Mishra, Montiel, and Spilimbergo (2011).

<sup>10</sup> Poor data quality is a serious obstacle in applying the VAR methodology, but no more so than for the application of structural approaches.

structural shocks, one of which is the monetary policy shock whose effects are the focus of the investigation.

5. Estimate the structural relationships specified in (4) and assess their empirical plausibility.
6. Determine the strength and reliability of the transmission mechanism by the size and precision of impulse response functions: specifically, the response of the indicator of aggregate demand to a monetary policy innovation.
7. To examine the roles of specific channels of monetary transmission, expand the VAR to include variables capturing those channels, and compare IRFs in which those variables are treated as endogenous and exogenous variables (as in Ramey 1993). Treating them as exogenous variables in the calculation of IRFs effectively holds these variables constant in the face of a monetary policy shock, and thus prevents them from serving as a conduit for transmitting the effects of monetary policy to aggregate demand. Comparing the response of an aggregate demand variable in an IRF in which a specific transmission variable is allowed to respond endogenously to a monetary policy shock to that in an IRF in which the transmission variable is held constant allows us to isolate the specific contribution of the transmission channel captured by that variable.

#### **IV. A Three-Variable VAR**

The first step in implementing this methodology for Tanzania is to choose the variables to be included in the VAR. As indicated above, the most parsimonious specification requires us to use three variables: an indicator of aggregate demand, a monetary policy variable, and an information variable that explains systematic changes in the policy variable.

Consider first the aggregate demand indicator. Since we are interested in examining the effects of monetary policies on aggregate demand, our results should be robust to the shape of the short-run aggregate supply curve in Tanzania. To achieve such robustness, it would be natural to include *two* indicators of aggregate demand in the VAR: both a measure of the price level as well as one of real output.<sup>11</sup> However, the need to restrict the sample to the decade of the 2000s requires us to use monthly data, since degrees of freedom would rapidly be exhausted with quarterly data. Unfortunately, since there is no readily-available indicator of aggregate economic activity at the monthly frequency this means that, at least as a first pass, transmission to aggregate demand will have to be examined through the effects of monetary policy on prices

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<sup>11</sup> This would allow us to pick up effects on aggregate demand whether the short-run aggregate supply curve is steep (so aggregate demand effects would primarily manifest themselves in the form of price changes) or flat (so effects would mainly show up in the form of changes in real activity).

only.<sup>12</sup> In the next section we will relax this constraint by employing a monthly indicator of broad economic activity constructed at the Bank of Tanzania, but not publicly available.

The choice of monetary policy variable is straightforward in this case. Since the announced monetary policy regime claims to use base money as the operational monetary policy instrument (a quantity rather than a price, and a specific quantity, out of a variety of possible choices), it is natural to adopt base money as the monetary policy indicator.

The next question is what information the BoT looks at in setting the value of base money. Because of information lags, it presumably cannot contemporaneously (on a monthly basis) observe the price level, but might be able to observe other variables that convey useful information about future price level developments. As indicated above, in light of the country's managed exchange rate regime, the nominal exchange rate would appear to be a likely candidate. The inclusion of the nominal exchange rate in the VAR has the added advantage that it potentially permits the investigation of monetary transmission through the exchange rate channel by examining the effect of monetary policy on the exchange rate, and of the exchange rate, in turn, on the price level.<sup>13</sup> In formulating its monetary policy, it is also quite likely that the BoT will react to observable external factors that are expected to affect the future price level in Tanzania. Failing to account for such factors would cause us to misinterpret exogenous changes in these factors as exogenous changes in monetary policy, and to erroneously attribute to monetary policy any effects on the price level and the exchange rate that are actually due to external shocks. To address this potential problem, we incorporate the potential effects of two such external factors, in the form of the world prices of food and energy. The small country assumption implies that both of these variables should be treated as exogenous in a VAR for Tanzania. By including contemporaneous values of these variables (along with their lags) in the VAR, we can ensure that the estimated VAR residuals are purged of any contemporaneous responses of the endogenous variables to these exogenous determinants.

A reasonable parsimonious VAR for Tanzania thus contains the logs of the shilling-dollar exchange rate, the core component of the Tanzanian CPI (the "headline" CPI minus its food and energy components), and base money as endogenous variables, while the logs of dollar indices of the world prices of food and energy are included as exogenous variables. Since our data are monthly, all of our estimated VARs will also include monthly dummies to capture seasonal effects.

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<sup>12</sup> This is not an ideal situation, because if the economy's short-run aggregate supply curve is sufficiently flat, changes in aggregate demand would primarily affect real output, rather than prices. Consequently, a finding of weak effects of monetary policy on the price level in Tanzania could indicate not weak monetary transmission, but rather a flat aggregate supply curve. This is an important caveat to bear in mind when interpreting the results below

<sup>13</sup> The BoT's use of broad money as an intermediate target suggests including broad money as an information variable. We begin by including the exchange rate as a single information variable, and in the next section examine the implications of including broad money as well.

### *1. Variable time series properties and VAR specification*

The time series for the three endogenous variables to be used in the VAR are plotted in Figure 2 below. All of them appear to contain a deterministic trend. Accordingly, we used an augmented Dickey-Fuller test to examine their time series properties. We could not reject the unit root null for the nominal exchange rate or the core component of the CPI, but could safely reject it ( $p < 0.01$ ) for the monetary base. Since the exchange rate and price level were both stationary in first differences, we conclude that the exchange rate and price level are both  $I(1)$ , while base money is  $I(0)$  (around a deterministic linear trend).<sup>14</sup> The printouts of the unit root tests for these three variables are provided in Appendix 1.

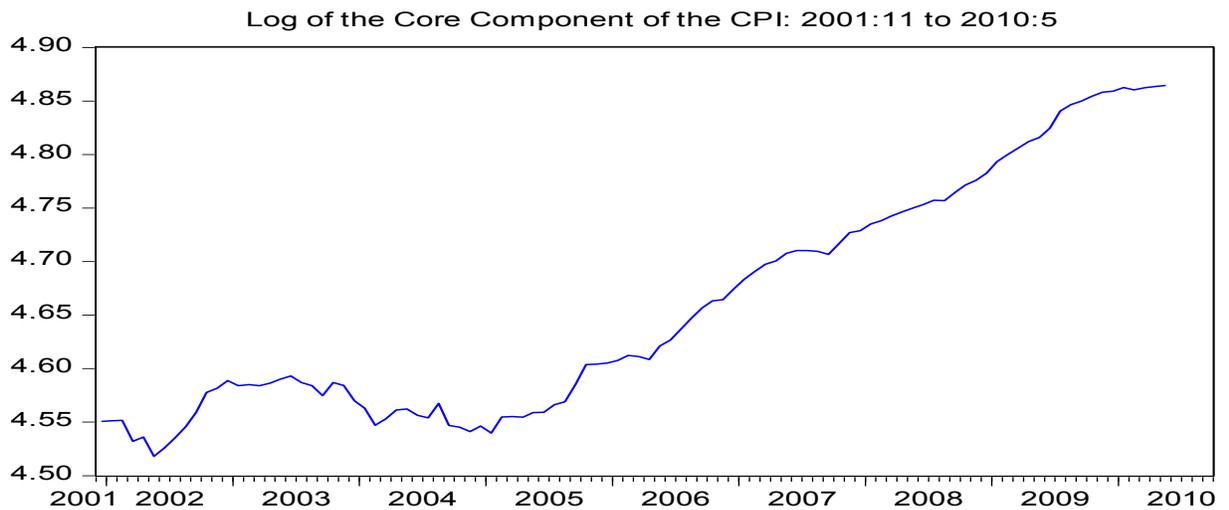
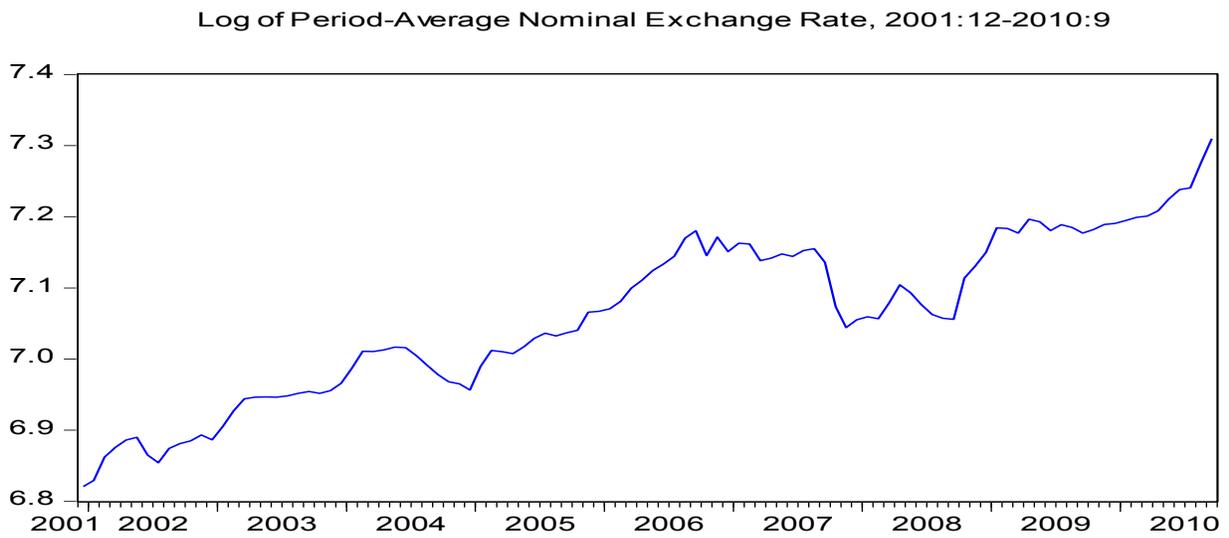
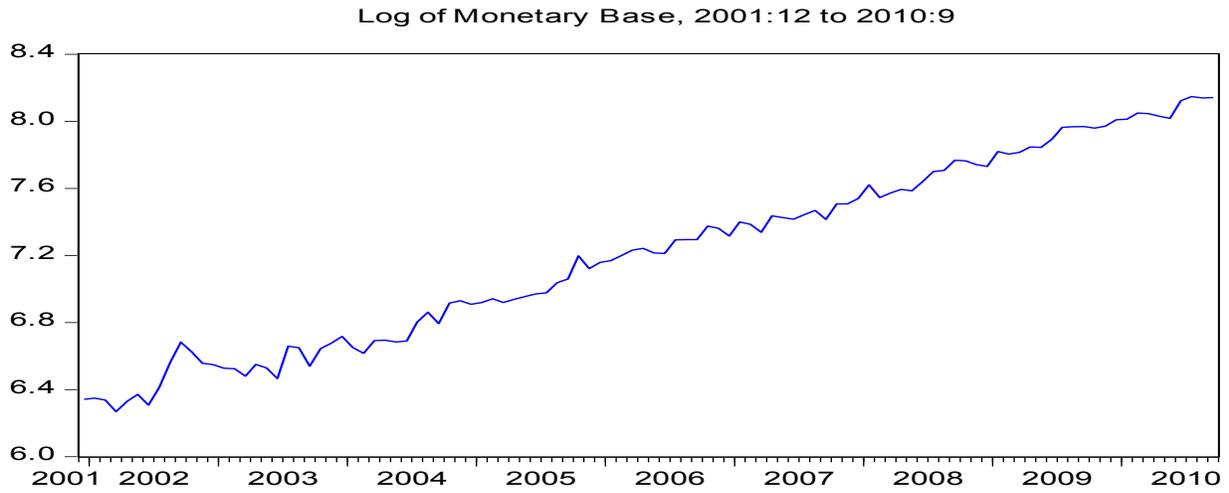
Since the exchange rate and price level are both nonstationary, the next step is to examine whether they are cointegrated. As reported in the appendix, the Johansen maximum eigenvalue and trace tests concur in finding that they are. In light of this result, the data do not require differencing to generate a stochastically-balanced VAR. We will therefore estimate the VAR in levels, so as to preserve the maximal information in the data. This “levels” VAR does not directly exploit the restrictions implied by cointegration, and therefore provides estimates of the VAR parameters that are consistent, not efficient.

Because all of the endogenous variables in our VAR appear to include a deterministic trend, and because our estimates are based on monthly data, we included a time trend and seasonal dummies as deterministic variables in the VAR. The choice of lag length was determined as the minimum number of lags necessary to remove all autocorrelation from the residuals, based on a Lagrange Multiplier (LM) test. We began with 12-month lags. Tests of lag length based on information criteria suggested very short lags (see Appendix 1). With two lags, the LM test could not reject the null hypothesis of no serial correlation in the residuals. Accordingly, all subsequent VARs for the three-variable system were estimated with two lags.

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<sup>14</sup> This result is somewhat puzzling, since over a long enough time span of data, monetary neutrality suggests that these three series should share the same order of integration. It is likely that the failure to confirm this is due to the limited time span of the data. This limitation is a recurring issue in the interpretation of the results below. Notice also that the monetary base displays only very modest fluctuations around its growth path. This is consistent with strict adherence to a reserve-money program constructed around a stable inflation target. Particularly after 2003, there is little evidence in Figure 2 of major policy activism by the Bank of Tanzania.

**Figure 2. Tanzania: Time Series Plots of VAR Variables**



## 2. Three-variable system: identification and impulse responses

The estimated VAR is the reduced form of a structural model linking the log of reserve money ( $m$ ), the log of the price level ( $p$ ), and the log of the bilateral nominal exchange rate against the US dollar ( $s$ ). That model can be expressed in the form:

$$Ay_t = B(L)Ly_t + Cx_t + DET_t + e_t, \quad (1)$$

where  $y_t = (s_t, m_t, p_t)'$  is the vector of endogenous variables,  $A$  is a 3x3 matrix of coefficients capturing the contemporaneous relationship among the endogenous variables,  $L$  is the lag operator (so  $Ly_t = y_{t-1}$ ),  $B(L) = B_0 + B_1L + B_2L^2 + \dots$  is a matrix polynomial in the lag operator, containing the lagged effects of the endogenous variables,  $C$  is a 3x2 matrix capturing the effects of the two exogenous variables,  $DET_t$  is a 3x1 vector of deterministic effects (the time trend and seasonal dummies), and  $e_t = (e^s_t, e^m_t, e^p_t)'$  is the vector of structural innovations, with  $E(e_t e_t') = \Sigma$ , a diagonal matrix, and  $E(e_t e_{t-j}') = 0$ . The estimated reduced-form VAR is:

$$y_t = A^{-1}B(L)Ly_t + A^{-1}Cx_t + A^{-1}DET_t + u_t, \quad (2)$$

where  $u_t = A^{-1}e_t$  is the vector of reduced-form residuals with  $E(u_t u_t') = \Omega = A^{-1}\Sigma A^{-1}$ , which is generally *not* diagonal. The reduced-form VAR yields an estimate of  $A^{-1}B(L)$ , as well as of  $u_t$  and  $\Omega$ .

What we are interested in are the dynamic effects of an exogenous monetary policy shock on the price level and the exchange rate. Notice that if  $A$  were a diagonal matrix, then  $\Omega$  would be as well. However, that is generally not the case, and it is not the case for the VAR described above. Table 2 presents the contemporaneous correlation coefficients among the residuals of the estimated 3-variable VAR, where LSPA is the log of the period-average exchange rate, LMO is the log of the monetary base, and LPC is the log of the “core” component of the Tanzanian CPI. Notice that the contemporaneous correlations of the residuals in the monetary base and price level equations with those in the exchange rate equation are quite weak, while those between residuals in the monetary base and price level equations are comparatively much stronger.

**Table 2. Correlation Matrix for VAR Residuals, 3-Variable System**

	LSPA	LMO	LPC
LSPA	1.000000	-0.025121	-0.081303
LMO	-0.025121	1.000000	0.365839
LPC	-0.081303	0.365839	1.000000

If the elements of  $A$  were known, we could trace out the dynamic effects of an exogenous monetary policy shock on the price level and the exchange rate (the impulse responses) by shocking  $e_t^m$  (the second element of  $e_t$ ) in:

$$y_t = A^{-1}B(L)y_t + A^{-1}Cx_t + A^{-1}DET_t + A^{-1}e_t, \quad (3)$$

and using this equation to solve for the present and all future values of  $y_t$ . Unfortunately, estimating the reduced-form VAR does not yield an estimate of  $A$ . It does, however, provide some restrictions on those elements.  $\Omega$  is an observed 3x3 symmetric matrix. It thus contains six distinct elements. By choice of units, we can set  $\Sigma = I$ , the identity matrix. In that case, we have  $\Omega = A^{-1}A^{-1'}$ . Because  $\Omega$  is symmetric, it contains six distinct elements, and this equation therefore provides six independent (nonlinear) restrictions on the nine distinct elements of  $A$ . With three additional independent restrictions, therefore, we can identify the remaining elements of  $A$  and compute the impulse responses.

#### a. Recursive identification

A common way to proceed is to assume that the contemporaneous interaction among the endogenous variables in the VAR is recursive. This would make  $A$  lower-triangular, and the three additional restrictions would consist of zero restrictions on the above-diagonal elements of  $A$ . The question becomes how to order the variables in the recursive chain. A common approach is to specify the recursive ordering on the basis of the existence of lags in the availability of information to the monetary authorities as well of lags in the effects of monetary policy.

A recursive identification can be based on the assumption that the BoT can observe the exchange rate continuously, but information on the price level is available to it only with a lag. This would imply placing the exchange rate before the monetary base in the recursive ordering, thereby relegating the price level to the bottom of the ordering. In that case the recursive ordering would run from the exchange rate to the stock of reserve money to the price level. An identification based on that ordering yields the impulse responses to a one-standard deviation monetary shock reported in Figure 3 below, with the dashed curves representing +/- two standard deviation bands.

The point estimates suggest that a monetary expansion increases the price level and depreciates the exchange rate relative to trend, with the effect dying out after about a year in the case of the exchange rate and much more slowly in the case of the price level. However, only the initial response of the price level (over a year or so) is statistically significant.<sup>15</sup> Quantitatively, the effects of a shock to the monetary base on the price level and the exchange

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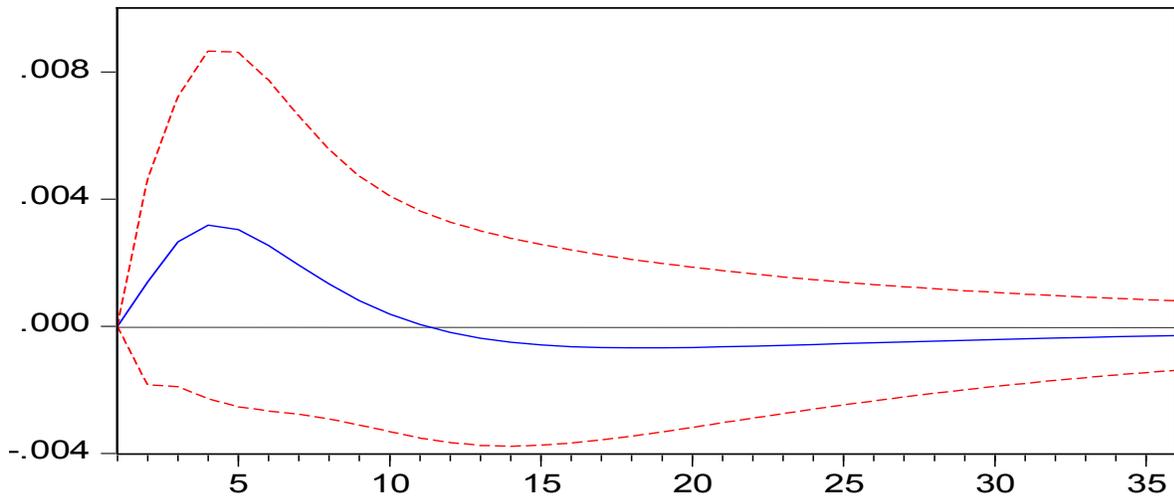
<sup>15</sup> Dropping the seasonal dummies from this specification made no appreciable difference to the IRFs.

rate are estimated to be small, with a peak response elasticity of about 0.09 in the case of the price level and about 0.08 in the case of the exchange rate.

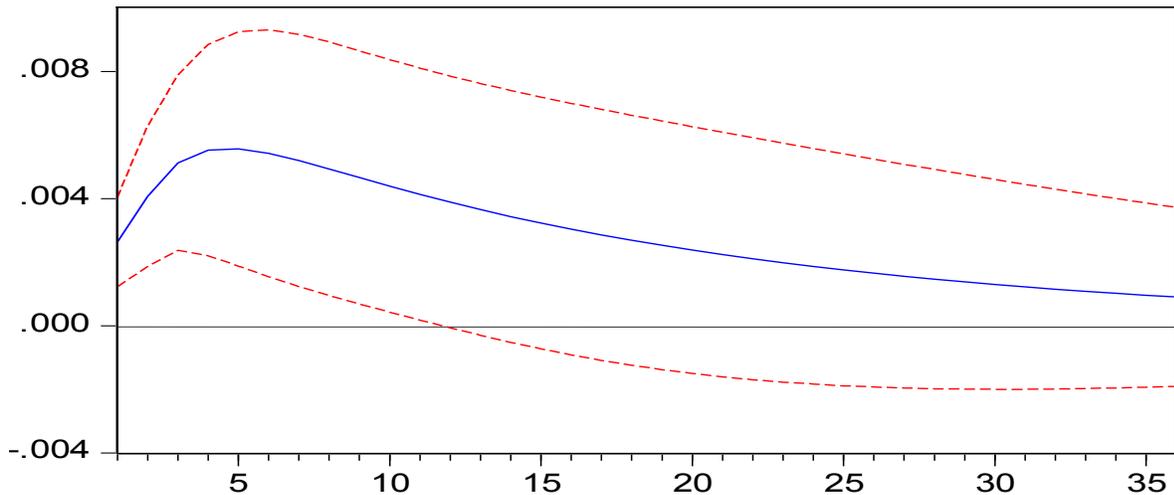
**Figure 3. Three-Variable System: Impulse Responses with Recursive Identification**

**Response to Cholesky One S.D. Innovations  $\pm 2$  S.E.**

**Response of LSPA to LMO**



**Response of LPC to LMO**



b. Structural identification

Note, however, that the identification used above implies that the exchange rate does not respond contemporaneously to monetary policy and the price level, while the price level *is*

affected contemporaneously by the exchange rate as well as by monetary policy. Neither of these assumptions is very attractive *ex ante* if the price level tends to be “sticky” in the short run, while the floating exchange rate behaves like an asset price, exhibiting “jumps” in response to new information, as in the Dornbusch (1976) model. A more attractive set of identifying assumptions under these familiar conditions is that the exchange rate is affected contemporaneously by exogenous changes both in monetary policy as well as in the price level, while the price level responds neither to the exchange rate nor to monetary policy within the month. The implied interactions between the reduced-form innovations (the  $u$ 's in equation (2)) and the structural shocks (the  $e$ 's in equation (1)) are given by:

$$u^s_t = a_{12} u^m_t + a_{13} u^p_t + e^s_t$$

$$u^m_t = a_{21} u^s_t + e^m_t$$

$$u^p_t = e^p_t,$$

where  $a_{ij}$  is the negative of the element in the  $i^{\text{th}}$  column and  $j^{\text{th}}$  row of the matrix  $A$ . The simultaneous interaction between  $m$  and  $s$  means, of course, that the contemporaneous model is no longer recursive. For this interpretation to be consistent with “leaning against the wind” monetary policy in a Dornbusch-like context we require that  $a_{21} < 0$  and  $a_{12} > 0$ .<sup>16</sup>

The impulse responses associated with this “structural” identification scheme are presented in Figure 4 below. These responses are qualitatively very different from those with the recursive identification. As would be expected, the exchange rate now jumps on impact (note that it was prevented from doing so under the recursive identification implemented in the last sub-section). Moreover, the depreciation of the nominal exchange rate in response to a monetary innovation is much larger (the peak elasticity is now about 1.2 percent, in comparison to 0.08 under the recursive identification), and the exchange rate depreciation is statistically significant up until the eighth month after the monetary shock. By contrast, the price level response is now negligible, and is not statistically significant over any horizon. The impulse responses of reserve money to an exchange rate shock (not shown) are negative both on impact and over a seven-month horizon, after which they become essentially zero (though they are statistically significant only for the first three months), consistent with a “leaning against the wind” monetary policy reaction function. However, the monetary base responds *positively* to a price level shock, suggesting a policy of accommodation, although the effects are statistically significant only over the first two months. Similarly, the response of the exchange rate to a price shock (though slightly negative on impact) is positive in the short run, as would be expected.

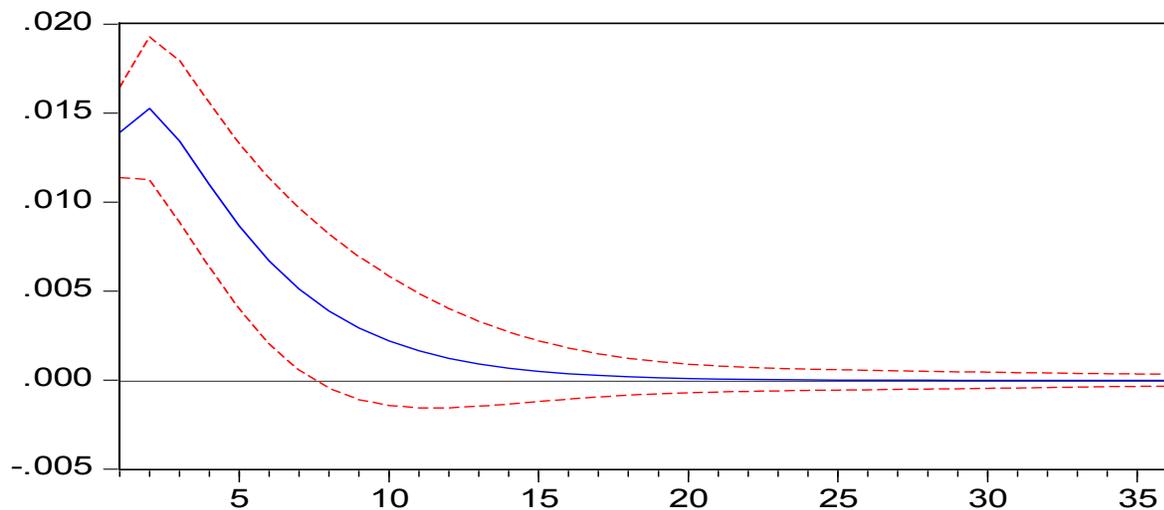
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<sup>16</sup> The sign of  $a_{13}$  is ambiguous.

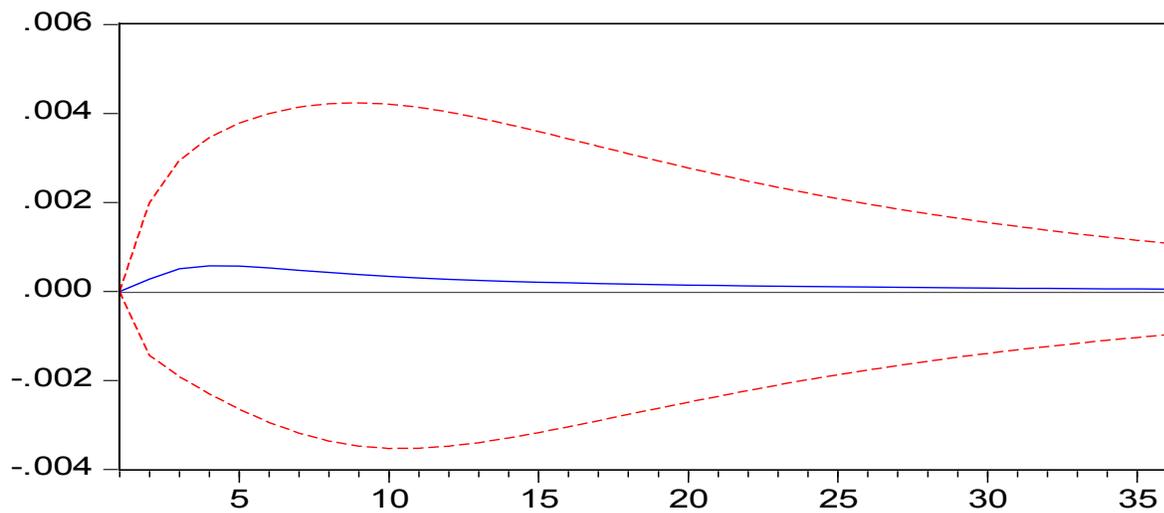
**Figure 4. Three-Variable System: Impulse Responses with Structural Identification**

**Response to Structural One S.D. Innovations  $\pm 2$  S.E.**

**Response of LSPA to Shock2**



**Response of LPC to Shock2**



## V. A Six-Variable VAR: Incorporating Broad Money, Output, and the Lending Rate

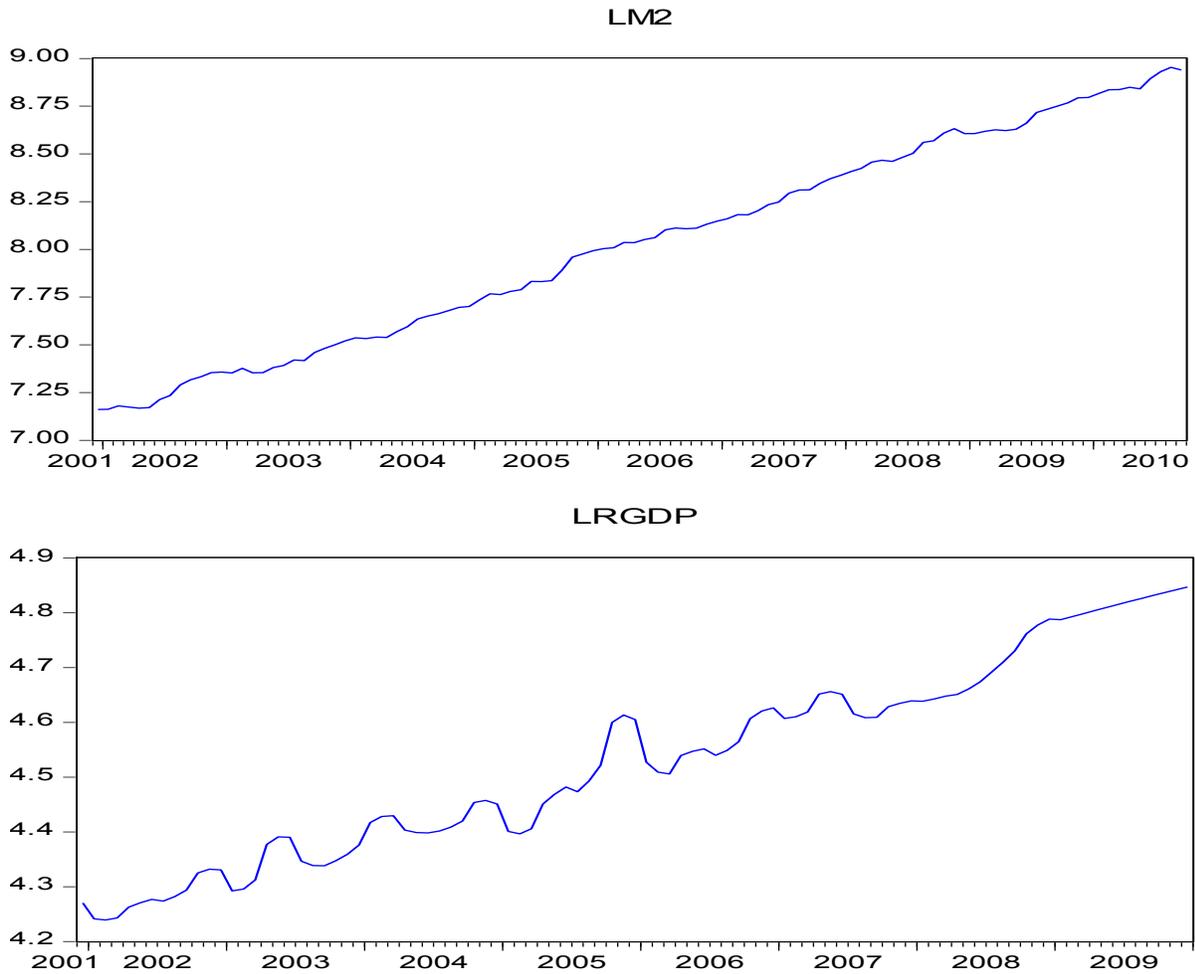
The preceding VAR is limited in several respects. First, it does not account of the role of broad money as an intermediate target – i.e., as an information variable in the BoT’s reaction function. This raises the possibility that the monetary policy “shocks” whose effects were investigated in the last section may not have been properly identified. Second, we cannot rule out that our inability to detect strong aggregate demand effects of monetary policy shocks on aggregate demand may be explained by a very flat short-run aggregate supply curve, so that movements in aggregate demand are reflected only in changes in output, and not in prices. We can address this possibility only by including some measure of real economic activity in the VAR. With both the domestic price level and an indicator of real economic activity included, weak effects of monetary policy on aggregate demand would be revealed in the form of economically and statistically insignificant effects on *both* prices and output. Weak effects on prices *or* output, with strong effects on the other, would suggest strong monetary transmission to aggregate demand in the face of a very flat or very steep short-run aggregate supply curve. Since we have found weak monetary policy effects on the price level, to discriminate between weak monetary transmission and a flat short-run aggregate supply curve we need to examine the effects of monetary policy shocks on real output. Third, our previous results do not allow us to determine whether the weakness of the monetary transmission process in Tanzania represents a weak effect of BoT actions on bank lending rates or weak effects of bank lending rates on aggregate demand – or possibly both. To address this question, we need to include bank lending rates in our empirical analysis.

To address these issues, in this section we expand the three-variable VAR of the last section to include broad money, a measure of real economic activity, and the bank lending rate.

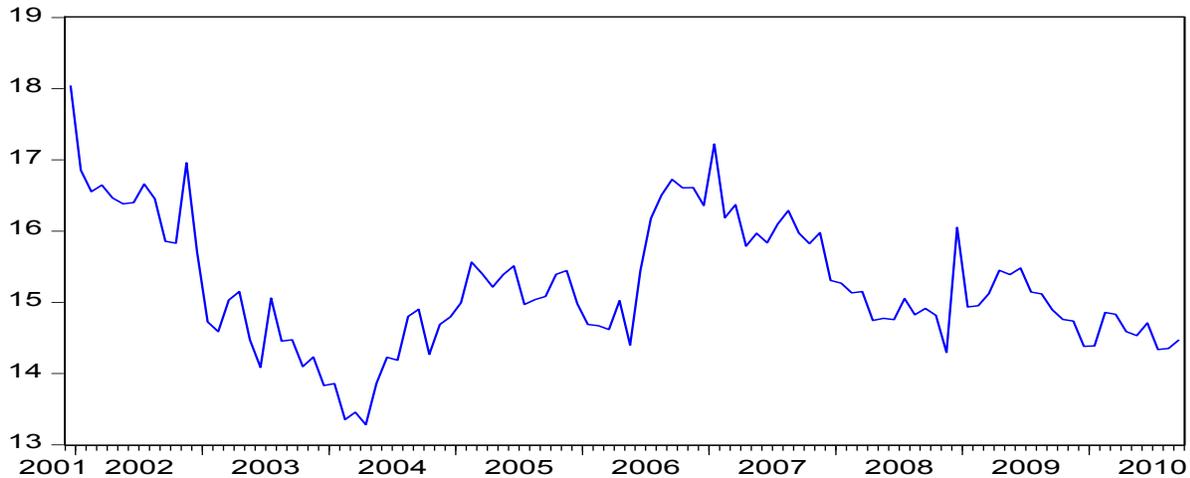
The major challenge in doing so concerns the inclusion of real economic activity. The problem with including real output in the VAR, as indicated previously, is that the short span of time over which the monetary transmission mechanism is likely to have been stable in Tanzania suggests estimating the VAR with monthly data, but monthly indicators of aggregate real economic activity are not available for Tanzania. One approach would be to use a proxy indicator that *is* available on a monthly basis. Unfortunately, many of the indicators that are typically used in that role are either not available or not likely to be representative of aggregate activity in the case of Tanzania. However, BoT staff have recently constructed an interpolated monthly real GDP index using a variety of indicators to conduct the interpolation from the quarterly series. Because this is not an official series, we have not used it in the estimation so far, but will do so in this section.

Figure 5 depicts the behavior of our three new variables (LM2, LRGDP, and LOAN\_RATE) over our sample period. LM2 appears to behave very similarly to the monetary base. Indeed, the series has a deterministic trend, but is stationary (see Appendix 1).

**Figure 5. Time Series Plots for Broad Money, Real GDP, and the Bank Lending Rate**



## LOAN\_RATE



LRGDP also clearly contains a linear trend, but in this case we cannot reject the unit root null, suggesting that fluctuations about this trend tend to be persistent. Since this series is likely to contain significant error, however, we remain agnostic about its time series properties. Finally, ADF tests suggest that the lending rate series is stationary (Appendix 1). Since Johansen tests suggest that it would not be inappropriate to treat LRGDP as cointegrated with LSPA and LPC (see Appendix 1), even if LRGDP is nonstationary we can retain our previous specification in levels. Accordingly, we simply add LM2, LRGDP, and LOAN\_RATE in levels to the three-variable VAR of Section IV.

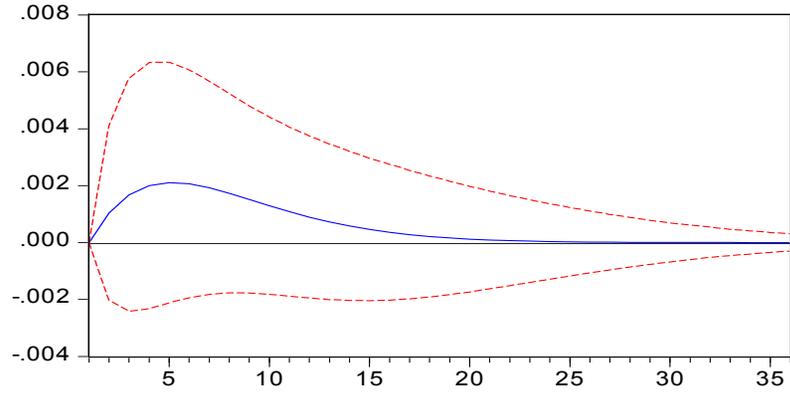
In this case, information criteria gave conflicting results about appropriate lag length for the VAR, so the choice of lag length was based on the LM test for the absence of serial correlation in the VAR residuals. To conserve degrees of freedom, we chose the minimum lag length consistent with white noise residuals, which proved to be one month (Appendix 1). To examine the implications of including the additional variables, we reproduce the impulse response exercises of the previous section. Figure 6 depicts the impulse responses derived from the recursive ordering LSPA, LM2, LMO, LOAN\_RATE, LPC, LRGDP, which allows only the exchange rate and broad money, but not the loan rate, price level, or real GDP to affect the monetary base contemporaneously. For both the exchange rate and the price level, the results closely resemble those of Figure 3: as we would expect, the monetary shock has positive effects on both the exchange rate and price level, with effects on the price level that are more prolonged than those on the exchange rate. However, the effects of including the additional variables are to make both the peak exchange rate and price level effects smaller than in the 3-variable system. As before, only the price level effect is statistically significant, albeit only over a seven-month horizon in the expanded system. Effects on real GDP are small and not statistically significant. Effects on the bank lending rate are counterintuitively *positive* over the first 10 months. In short,

the results from recursive identification of monetary shocks provide extremely weak evidence -- at best -- for the presence of an effective monetary transmission channel in Tanzania.

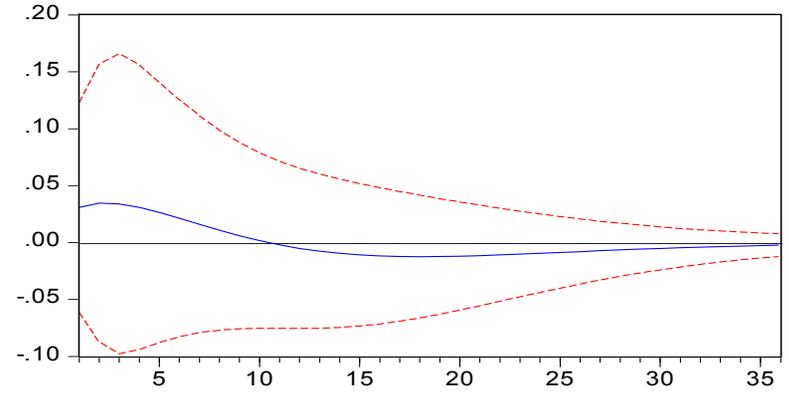
**Figure 6. Six-Variable System: Impulse Responses with Recursive Identification**

Response to Cholesky One S.D. Innovations  $\pm 2$  S.E.

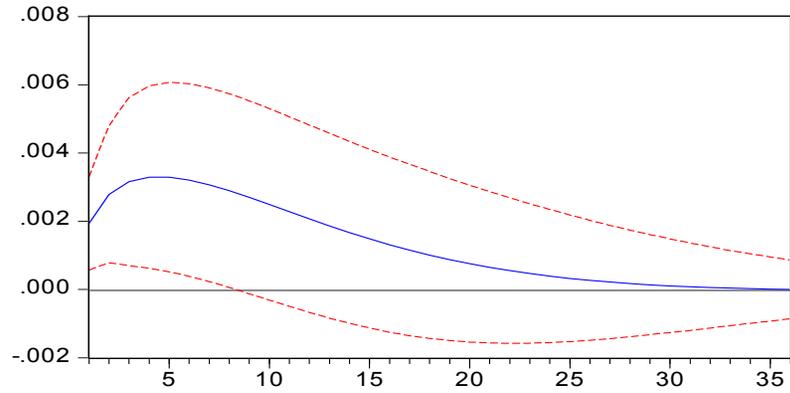
Response of LSPA to LMO



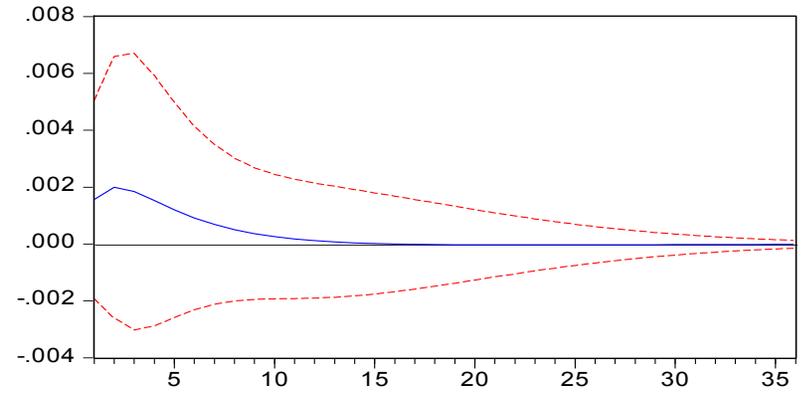
Response of LOAN\_RATE to LMO



Response of LPC to LMO



Response of LRGDP to LMO



To implement the structural identification we use the following model:

$$u_t^y = e_t^y$$

$$u_t^p = a_{21} u_t^y + e_t^p$$

$$u_t^m = a_{34} u_t^{m2} + a_{35} u_t^s + e_t^m$$

$$u_t^{m2} = a_{41} u_t^y + a_{42} u_t^p + a_{43} u_t^m + e_t^{m2}$$

$$u_t^s = a_{51} u_t^y + a_{52} u_t^p + a_{53} u_t^m + a_{54} u_t^{m2} + a_{56} u_t^r + e_t^s,$$

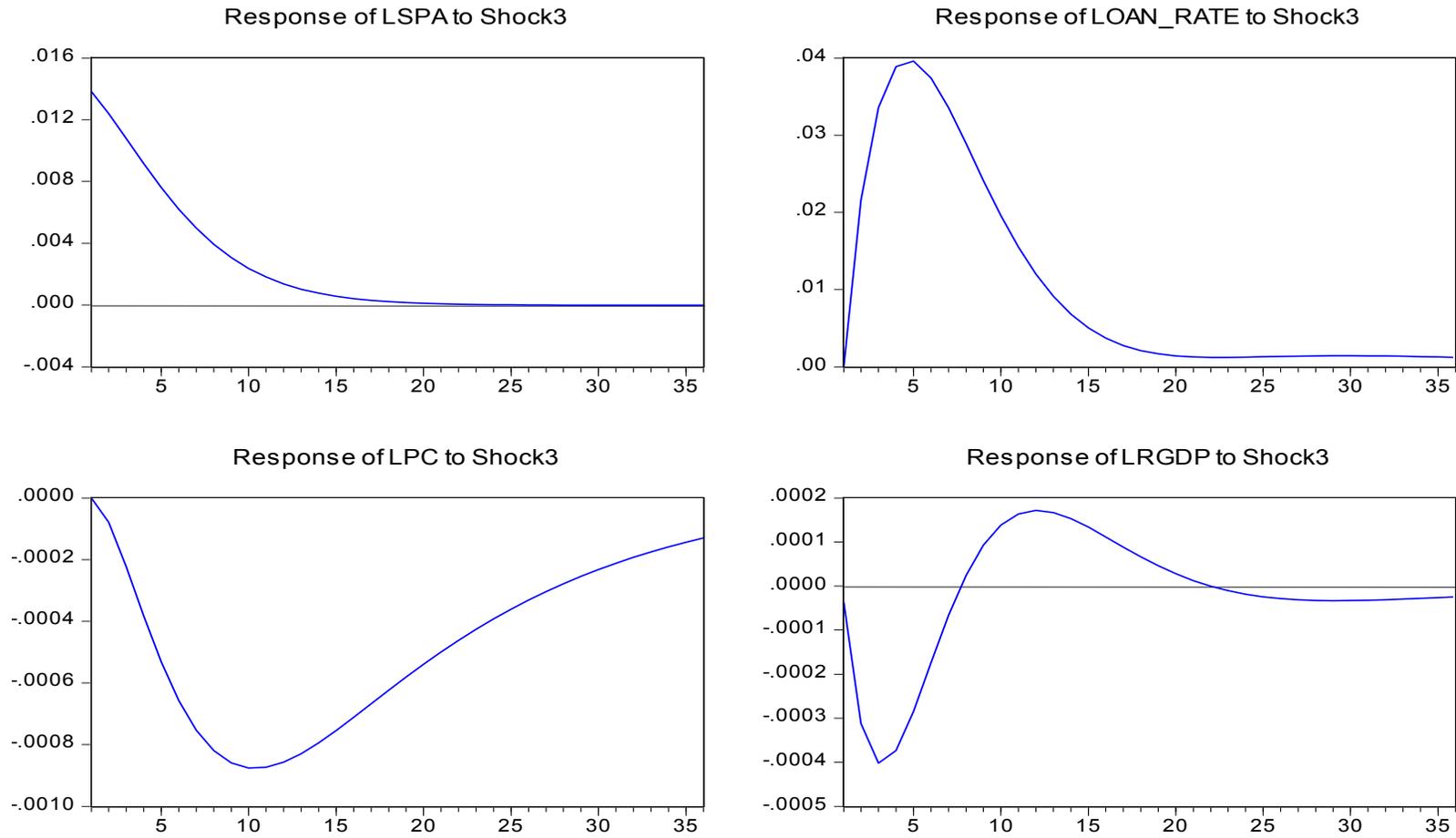
$$u_t^r = a_{61} u_t^y + a_{62} u_t^p + a_{63} u_t^m + a_{64} u_t^{m2} + a_{65} u_t^s + e_t^r,$$

This specification does not allow real output to be affected by the other endogenous variables within the month, but allows supply shocks to affect the price level at the monthly frequency. On the assumption that they are both unobservable within the month, monetary policy is unaffected by contemporary values of the price level and real output, but reacts both to broad money and the exchange rate. Broad money depends on the monetary base, but output and price level innovations potentially affect the money multiplier. Finally, we do not impose restrictions on the short-run response of the exchange rate and the bank lending rate to any of the other variables

Figure 7 depicts the resulting impulse response functions. Those functions had very wide standard error bands – so much so that including them in Figure 7 would require the use of a scale that completely obscures the movements of the price level and real output. The immediate implication is, of course, that we are unable to identify any statistically significant monetary policy effects with our six-variable model. More importantly, however, the point estimates of dynamic monetary policy effects are not consistent with theoretical priors. For example, although a monetary expansion causes the exchange to depreciate as expected, it results in an *increase* in the bank lending rate and a *reduction* in the price level. While the expansion has a cyclical effect on real GDP, that effect proves to be *negative* over the first eight months after the expansion.

**Figure 7. Six-Variable System: Impulse Responses with Structural Identification**

Response to Structural One S.D. Innovations



## VI. Conclusions

In short, we have been able to find statistically significant price level effects of monetary policy only in the context of recursive identification schemes applied both to the three- as well as six-variable models. However, such effects, while statistically significant, are economically insignificant. With the more plausible structural identification scheme, we detect very weak monetary policy effects on the exchange rate as long as real output is not in the system, but essentially no direct or indirect effect (through exchange rate pass-through) on prices. The inclusion of broad money as an information variable in the BoT's reaction function, as well as real output and the bank lending rate as endogenous variables in the system (the former to enable us to distinguish between weak monetary transmission and a flat short-run aggregate supply curve, and the latter to help us interpret our weak transmission result) weakens the price level effects under recursive identification, and reverses it under structural identification (though in this case the effect is not statistically significant). We found neither statistically nor economically significant effects on real output in our six-variable system. This suggests that weak monetary transmission, rather than a flat short-run aggregate supply curve, explains the results in the three-variable model. The counterintuitive movements of the bank lending rate under both identification schemes are consistent with this interpretation. Overall, then, we are unable to provide strong evidence of effective monetary transmission in Tanzania.

Our results suggest that the Bank of Tanzania has limited scope for short-run stabilization policy not because it lacks the monetary autonomy to alter liquidity conditions in banks, but because changes in bank liquidity do not translate reliably into changes in bank behavior. Transmission to the loan rate appears to be particularly weak. One hypothesis consistent with this is that the banking sector interprets most deviations of the monetary base from trend as temporary shocks, and adjusts to them by altering its excess reserves. A regression of the M2 multiplier on the deviation of the log of base money from trend, for example, produces a negative and highly significant coefficient on the base-money deviation, with an  $R^2$  of more than 70 percent. In our six-variable VAR, the contemporaneous response of M2 to base money ( $a_{43}$  in the six-variable structural VAR) is actually negative, though very small and not statistically significant.

Poor identification is of course the leading alternative to our conclusion. A particular concern is the difficulty, in a low-income country with a large agricultural sector, of distinguishing aggregate demand shocks from shocks to aggregate supply. In an industrial-country context, real GDP is typically entered either as the GDP gap or, as in our application, in combination with a deterministic trend that picks up long-run aggregate supply. The real GDP equation then refers to aggregate demand and the price equation to short-run aggregate supply. In Tanzania, however, real GDP may be driven substantially or even primarily by temporary supply shocks. In this case, innovations in detrended real GDP reflect a combination of supply and demand shocks. If the monetary authority responds asymmetrically to these two types of shocks, the VAR coefficients will be imprecisely estimated and the impulse responses correspondingly

insignificant. We have investigated this concern by controlling for rainfall shocks as an additional exogenous variable in the VARs. These shocks are an important determinant of GDP in Tanzania, given sparse irrigation cover and the consequent reliance of agricultural supply on rainfall (the industrial sector is rain-dependent as well, via the supply of hydroelectric power). Controlling for these shocks should strengthen the identification of real GDP as aggregate demand. We find that our results are qualitatively unchanged.

The natural question is whether our weak results reflect the facts on the ground in Tanzania or are somehow an artifact of our estimation strategy. Our descriptive overview of the role of the financial sector in Tanzania makes a plausible case for the “facts on the ground” interpretation of our results. However, further work is required before this conclusion can be drawn with much confidence. In particular, we have focused on this paper on the effects of monetary policy shocks on aggregate demand, as indicated through changes in the price level and an interpolated estimate of monthly real output. To interpret these results, it would be desirable to complement these aggregate estimates with micro-based evidence of how individual banks actually respond to monetary policy shocks.

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## Appendix 1. Estimation Output

### 1. Unit root tests for the log of the monetary base (LMO), the log of the core price index (LPC), and the period-average nominal shilling-dollar index (SPA).

#### Null Hypothesis: LMO has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=12)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-5.541965	0.0001
Test critical values:		
1% level	-4.047795	
5% level	-3.453179	
10% level	-3.152153	

\*MacKinnon (1996) one-sided p-values.

#### Augmented Dickey-Fuller Test Equation

Dependent Variable: D(LMO)

Method: Least Squares

Date: 09/20/11 Time: 13:59

Sample (adjusted): 2002M01 2010M09

Included observations: 105 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LMO(-1)	-0.455649	0.082218	-5.541965	0.0000
C	2.865451	0.514383	5.570652	0.0000
@TREND(2001M12)	0.008153	0.001473	5.536152	0.0000
R-squared	0.231745	Mean dependent var		0.017145
Adjusted R-squared	0.216681	S.D. dependent var		0.053985
S.E. of regression	0.047780	Akaike info criterion		-3.216275
Sum squared resid	0.232856	Schwarz criterion		-3.140448
Log likelihood	171.8545	Hannan-Quinn criter.		-3.185549
F-statistic	15.38421	Durbin-Watson stat		1.971459
Prob(F-statistic)	0.000001			

#### Null Hypothesis: DF\_LPC has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=12)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.487143	0.8278
Test critical values:		
1% level	-4.051450	
5% level	-3.454919	
10% level	-3.153171	

\*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation  
 Dependent Variable: D(DF\_LPC)  
 Method: Least Squares  
 Date: 09/20/11 Time: 13:24  
 Sample (adjusted): 2002M01 2010M05  
 Included observations: 101 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DF_LPC(-1)	-0.027072	0.018204	-1.487143	0.1402
C	0.121483	0.081623	1.488349	0.1399
@TREND(2001M12)	0.000151	6.63E-05	2.269371	0.0254
R-squared	0.076406	Mean dependent var		0.003108
Adjusted R-squared	0.057557	S.D. dependent var		0.007291
S.E. of regression	0.007078	Akaike info criterion		-7.034383
Sum squared resid	0.004910	Schwarz criterion		-6.956706
Log likelihood	358.2363	Hannan-Quinn criter.		-7.002937
F-statistic	4.053596	Durbin-Watson stat		1.735837
Prob(F-statistic)	0.020351			

**Null Hypothesis: LSPA has a unit root**

Exogenous: Constant, Linear Trend  
 Lag Length: 1 (Automatic - based on SIC, maxlag=12)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.542572	0.3075
Test critical values:		
1% level	-4.047795	
5% level	-3.453179	
10% level	-3.152153	

\*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation  
 Dependent Variable: D(LSPA)  
 Method: Least Squares  
 Date: 09/20/11 Time: 14:07  
 Sample: 2002M01 2010M09  
 Included observations: 105

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LSPA(-1)	-0.091899	0.036144	-2.542572	0.0125
D(LSPA(-1))	0.329247	0.095549	3.445833	0.0008
C	0.635153	0.248663	2.554272	0.0121
@TREND(2002M01)	0.000320	0.000132	2.426678	0.0170
R-squared	0.134973	Mean dependent var		0.004656
Adjusted R-squared	0.109279	S.D. dependent var		0.016101
S.E. of regression	0.015195	Akaike info criterion		-5.498300
Sum squared resid	0.023321	Schwarz criterion		-5.397197
Log likelihood	292.6607	Hannan-Quinn criter.		-5.457331
F-statistic	5.253130	Durbin-Watson stat		1.976957
Prob(F-statistic)	0.002076			

## 2. Test for cointegration between LPC and LSPA

Sample (adjusted): 2003M01 2010M05  
 Included observations: 89 after adjustments  
 Trend assumption: Linear deterministic trend  
 Series: LPC LSPA  
 Lags interval (in first differences): 1 to 12

### Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.173741	17.02335	15.49471	0.0292
At most 1	0.000427	0.038007	3.841466	0.8454

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

\* denotes rejection of the hypothesis at the 0.05 level

\*\*MacKinnon-Haug-Michelis (1999) p-values

### Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.173741	16.98535	14.26460	0.0181
At most 1	0.000427	0.038007	3.841466	0.8454

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

\* denotes rejection of the hypothesis at the 0.05 level

\*\*MacKinnon-Haug-Michelis (1999) p-values

### Unrestricted Cointegrating Coefficients (normalized by b\*S11\*b=I):

LPC	LSPA
-10.87181	21.84826
15.79722	-3.954081

### Unrestricted Adjustment Coefficients (alpha):

D(LPC)	0.001925	6.61E-05
D(LSPA)	-0.004087	0.000211

1 Cointegrating Equation(s):            Log likelihood            597.0712

### Normalized cointegrating coefficients (standard error in parentheses)

LPC	LSPA
1.000000	-2.009625
	(0.39819)

### Adjustment coefficients (standard error in parentheses)

D(LPC)	-0.020932
	(0.00723)
D(LSPA)	0.044438
	(0.01858)

### 3. Tests of lag order based on information criteria: 3-variable VAR

VAR Lag Order Selection Criteria

Endogenous variables: LSPA LMO LPC

Exogenous variables: C @TREND DUM\_2 DUM\_3 DUM\_4 DUM\_5 DUM\_6 DUM\_7 DUM\_8 DUM\_9  
DUM\_10 DUM\_11 DUM\_12 LW\_FOOD LW\_ENERGY

Date: 11/04/11 Time: 14:56

Sample: 2001M12 2010M09

Included observations: 88

Lag	LogL	LR	FPE	AIC	SC	HQ
0	553.4902	NA	1.94e-09	-11.55660	-10.28978	-11.04623
1	766.1339	338.2967*	1.91e-11*	-16.18486*	-14.66468*	-15.57242*
2	770.7983	7.102704	2.13e-11	-16.08633	-14.31278	-15.37181
3	780.6401	14.31524	2.12e-11	-16.10546	-14.07854	-15.28886
4	783.9438	4.580195	2.46e-11	-15.97600	-13.69572	-15.05733
5	787.4544	4.627546	2.85e-11	-15.85124	-13.31760	-14.83050
6	796.6892	11.54354	2.93e-11	-15.85657	-13.06957	-14.73376
7	799.6224	3.466554	3.49e-11	-15.71869	-12.67832	-14.49380
8	807.1794	8.415705	3.77e-11	-15.68590	-12.39216	-14.35893
9	819.1231	12.48655	3.72e-11	-15.75280	-12.20570	-14.32376
10	828.1295	8.801756	3.98e-11	-15.75294	-11.95248	-14.22183
11	838.4073	9.343421	4.18e-11	-15.78198	-11.72816	-14.14880
12	847.9526	8.026708	4.54e-11	-15.79438	-11.48719	-14.05912

\* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

#### 4. Test for residual autocorrelation: 3-variable VAR

VAR Residual Portmanteau Tests for Autocorrelations  
Null Hypothesis: no residual autocorrelations up to lag h  
Date: 11/04/11 Time: 15:02  
Sample: 2001M12 2010M09  
Included observations: 97

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	0.371310	NA*	0.375178	NA*	NA*
2	1.188754	NA*	1.209831	NA*	NA*
3	4.735517	NA*	4.869789	NA*	NA*
4	6.657651	0.6727	6.874595	0.6502	9
5	16.99086	0.5237	17.76939	0.4709	18
6	24.32057	0.6125	25.58237	0.5419	27
7	26.54280	0.8749	27.97745	0.8280	36
8	29.86264	0.9598	31.59570	0.9347	45
9	37.52524	0.9570	40.04198	0.9214	54
10	44.06764	0.9665	47.33637	0.9293	63
11	64.19517	0.7322	70.03835	0.5435	72
12	79.44855	0.5280	87.44516	0.2927	81
13	85.82752	0.6049	94.81134	0.3439	90

\*The test is valid only for lags larger than the VAR lag order.  
df is degrees of freedom for (approximate) chi-square distribution  
\*df and Prob. may not be valid for models with exogenous variables

## 5. Unit root test for LM2, LRGDP, and LOAN\_RATE

Null Hypothesis: LM2 has a unit root  
 Exogenous: Constant, Linear Trend  
 Lag Length: 0 (Automatic - based on SIC, maxlag=12)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-3.651651	0.0302
Test critical values:		
1% level	-4.047795	
5% level	-3.453179	
10% level	-3.152153	

\*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation  
 Dependent Variable: D(LM2)  
 Method: Least Squares  
 Date: 12/02/11 Time: 15:19  
 Sample (adjusted): 2002M01 2010M09  
 Included observations: 105 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LM2(-1)	-0.210663	0.057690	-3.651651	0.0004
C	1.508606	0.408831	3.690044	0.0004
@TREND(2001M12)	0.003737	0.001018	3.668724	0.0004
R-squared	0.116983	Mean dependent var		0.016933
Adjusted R-squared	0.099669	S.D. dependent var		0.017399
S.E. of regression	0.016510	Akaike info criterion		-5.341595
Sum squared resid	0.027802	Schwarz criterion		-5.265768
Log likelihood	283.4337	Hannan-Quinn criter.		-5.310868
F-statistic	6.756516	Durbin-Watson stat		1.698133
Prob(F-statistic)	0.001756			

Null Hypothesis: LRGDP has a unit root  
 Exogenous: Constant, Linear Trend  
 Lag Length: 10 (Automatic - based on SIC, maxlag=11)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-3.035330	0.1289
Test critical values:		
1% level	-4.068290	
5% level	-3.462912	
10% level	-3.157836	

\*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation  
 Dependent Variable: D(LRGDP)  
 Method: Least Squares  
 Date: 02/07/12 Time: 14:33  
 Sample (adjusted): 2002M11 2009M12  
 Included observations: 86 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LRGDP(-1)	-0.211205	0.069582	-3.035330	0.0033
D(LRGDP(-1))	0.927001	0.115208	8.046354	0.0000
D(LRGDP(-2))	0.305068	0.130903	2.330489	0.0225
D(LRGDP(-3))	-1.324886	0.135289	-9.792991	0.0000
D(LRGDP(-4))	1.214550	0.193164	6.287654	0.0000
D(LRGDP(-5))	0.267475	0.184525	1.449530	0.1515
D(LRGDP(-6))	-1.043223	0.187299	-5.569839	0.0000
D(LRGDP(-7))	0.870996	0.194586	4.476152	0.0000
D(LRGDP(-8))	0.101874	0.121037	0.841678	0.4027
D(LRGDP(-9))	-0.481869	0.121224	-3.975019	0.0002
D(LRGDP(-10))	0.380609	0.107822	3.529989	0.0007
C	0.890300	0.292066	3.048290	0.0032
@TREND(2001M12)	0.001309	0.000422	3.103607	0.0027
R-squared	0.813916	Mean dependent var		0.006073
Adjusted R-squared	0.783326	S.D. dependent var		0.021355
S.E. of regression	0.009941	Akaike info criterion		-6.245953
Sum squared resid	0.007213	Schwarz criterion		-5.874947
Log likelihood	281.5760	Hannan-Quinn criter.		-6.096641
F-statistic	26.60792	Durbin-Watson stat		2.001931
Prob(F-statistic)	0.000000			

Null Hypothesis: LOAN\_RATE has a unit root  
 Exogenous: Constant, Linear Trend  
 Lag Length: 0 (Automatic - based on SIC, maxlag=12)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.075806	0.0092
Test critical values:		
1% level	-4.046925	
5% level	-3.452764	
10% level	-3.151911	

\*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation  
 Dependent Variable: D(LOAN\_RATE)  
 Method: Least Squares  
 Date: 02/07/12 Time: 14:39  
 Sample: 2001M12 2010M09  
 Included observations: 106

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOAN_RATE(-1)	-0.185309	0.045466	-4.075806	0.0001
C	2.769401	0.715171	3.872362	0.0002
@TREND(2001M12)	0.000323	0.001421	0.227237	0.8207
R-squared	0.148087	Mean dependent var		-0.042393
Adjusted R-squared	0.131545	S.D. dependent var		0.468937
S.E. of regression	0.437007	Akaike info criterion		1.210158
Sum squared resid	19.67043	Schwarz criterion		1.285538
Log likelihood	-61.13838	Hannan-Quinn criter.		1.240710
F-statistic	8.952168	Durbin-Watson stat		2.263588
Prob(F-statistic)	0.000260			

## 6. Test for cointegration among LPC, LSPA, and LRGDP

Date: 02/07/12 Time: 14:53  
 Sample (adjusted): 2003M01 2009M12  
 Included observations: 84 after adjustments  
 Trend assumption: Linear deterministic trend (restricted)  
 Series: LSPA LPC LRGDP  
 Lags interval (in first differences): 1 to 2

### Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.317268	56.79941	42.91525	0.0012
At most 1	0.205357	24.74055	25.87211	0.0687
At most 2	0.062622	5.432159	12.51798	0.5355

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

\* denotes rejection of the hypothesis at the 0.05 level

\*\*MacKinnon-Haug-Michelis (1999) p-values

### Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.317268	32.05886	25.82321	0.0066
At most 1	0.205357	19.30839	19.38704	0.0513
At most 2	0.062622	5.432159	12.51798	0.5355

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

\* denotes rejection of the hypothesis at the 0.05 level

\*\*MacKinnon-Haug-Michelis (1999) p-values

### Unrestricted Cointegrating Coefficients (normalized by b\*S11\*b=l):

			@TREND(79M01 )
LSPA	LPC	LRGDP	
13.63831	10.64288	-40.95551	0.181681
10.86032	-11.81743	11.77333	-0.026123
-20.50047	-17.00419	-1.573314	0.147504

### Unrestricted Adjustment Coefficients (alpha):

D(LSPA)	-0.005109	-0.002668	0.002823
D(LPC)	0.001085	0.002399	0.000818
D(LRGDP)	0.009690	-0.002626	0.001550

1 Cointegrating Equation(s):      Log likelihood      765.7635

### Normalized cointegrating coefficients (standard error in parentheses)

			@TREND(79M01 )
LSPA	LPC	LRGDP	
1.000000	0.780367	-3.002975	0.013321
	(0.37228)	(0.49613)	(0.00291)



## 7. Test for residual autocorrelation: 6-variable VAR

VAR Residual Serial Correlation LM Tests  
Null Hypothesis: no serial correlation at lag  
order h  
Date: 02/07/12 Time: 16:05  
Sample: 2003M01 2010M05  
Included observations: 84

Lags	LM-Stat	Prob
1	42.23140	0.2196
2	52.48614	0.0373
3	64.77477	0.0023
4	27.81142	0.8339
5	30.87207	0.7109
6	34.71676	0.5296
7	39.41622	0.3197
8	35.78230	0.4789
9	18.48184	0.9931
10	43.54703	0.1811
11	34.83058	0.5241

Probs from chi-square with 36 df.

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